INFRASONIC OBSERVATION OF A SEVERE WEATHER SYSTEM

V. H. GOERKE AND M. W. WOODWARD

Institute for Telecommunication Sciences and Aeronomy*, Environmental Science Services Administration, Boulder, Colo.

ABSTRACT

The coherent atmospheric pressure waves traveling at sonic velocities from a squall line storm 20–75 km. distant were observed in detail for a period of 100 min. The measurements indicate that the infrasonic wave was generated in or near the leading edge of the storm. Infrasonic waves were not observed from funnel clouds or from the heavy rain clouds accompanying the storm front.

1. INTRODUCTION

The graphic records from an array of microphones located near Boulder, Colo., frequently show small-amplitude pressure waves traveling at sonic velocities. These correlatable fluctuations originate from various sources such as severe weather systems, ionospheric phenomena, etc. [1, 2, 3, 4]. The equipment used is described in the references.

The four pickup microphones used at Boulder are located 6–12 km. apart in a quadrilateral array. A distributed low-pass pickup system consisting of 300 meters of pipe vented to the atmosphere through 100 evenly distributed capillaries is used to reduce the effects of local turbulence [5]. The half-amplitude pass band of the amplifiers feeding the graphic recorders is 9–70 sec. per cycle. Under conditions of very low local noise the system sensitivity permits the observation of amplitudes as low as 0.2 dynes/cm.^{2} zero-to-peak.

In order to determine the azimuth of arrival of infrasonic waves the four graphic records of the pressure variations at the microphones are superposed on a light table and adjusted for best fit of the wave forms as seen in figure 1. Time differences of arrival at the microphones are scaled from the superposed records, and from the distances and azimuths between the microphones it is then possible to compute the azimuth to the source by a simple trigonometric computation. Because of the rapid rate of change of azimuth for this event it was necessary to scale the azimuths in small, 5–10 min., increments. The same azimuth information was also obtained by use of an analog correlator [6]. The analog correlator automatically performs the same function electronically as the visual superposition of graphic tape records, using movable search heads to line up the wave forms on the analog magnetic tape records.

*Formerly the Central Radio Propagation Laboratory of the National Bureau of Standards.

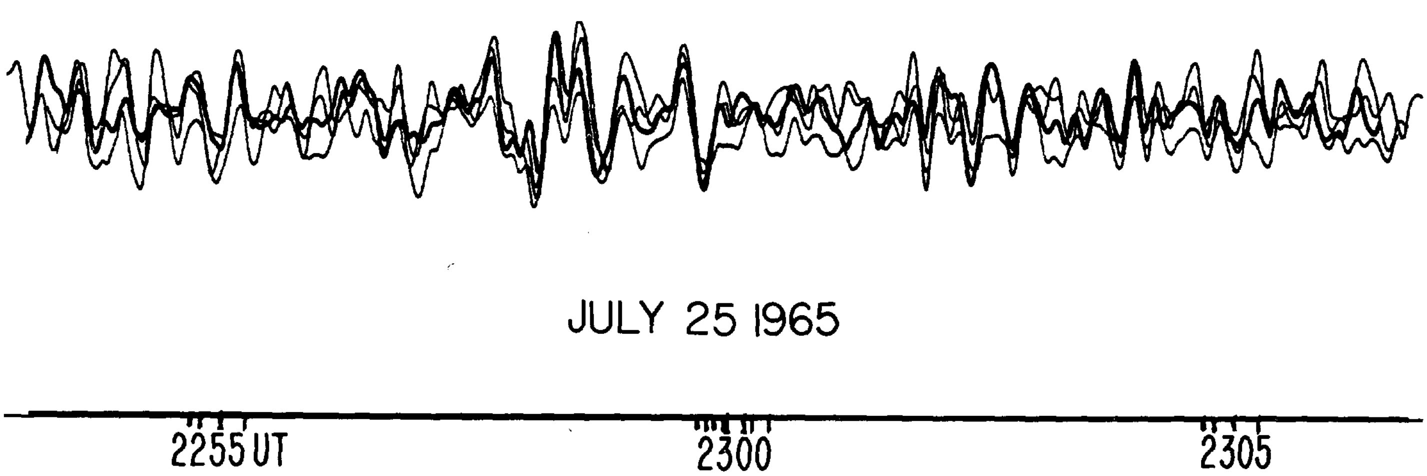

FIGURE 1.—Superposed graphic recorder traces adjusted for best fit near 2300 UT.

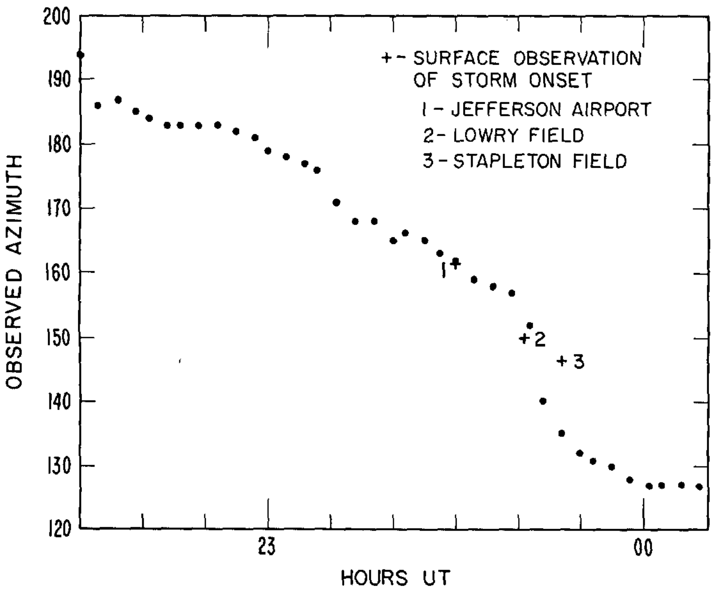

FIGURE 2.—Time variation of azimuth of infrasonic waves from rapidly moving storm.

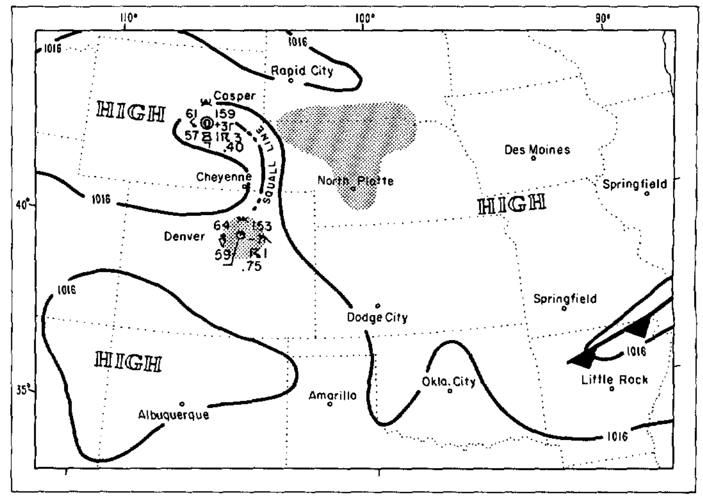

FIGURE 3.—Part of Weather Bureau map for 0600 UT, July 26, 1965, showing squall line.

The correlator gives the average azimuth over an 8-min. interval. The data shown in the plot of figure 2 were scaled in this manner. These scaled azimuths are in very good agreement with data scaled from the superposed graphic records.

More than 150 infrasonic events associated with severe weather have been observed in Boulder, Colo., since 1963 (report in preparation).

The sources of nearly all observed severe weather systems have been too far distant to determine what part of the system was responsible for the infrasonic event. The nearby severe weather event of July 25, 1965 offered a unique opportunity for such a study.

First, the storm system was close enough to our microphones for us to determine what part of the storm system was responsible for the infrasonic emission.

Second, the very low background noise at our microphones permitted us to track the movement of the infrasonic source in detail for 100 min.—quite unusual for a nearby storm.

Third, the storm's lateral movement across the line of sight from our microphones for much of the event permitted meaningful azimuth indications.

Fourth, the storm system moved across or near five airports where competent observers recorded the onset and other details of the storm (surface observations).

Fifth, other infrasonic measurements on close-in events have shown that the infrasonic emission is generated well above the surface of the earth (high angle of arrival).

2. OBSERVATION OF THE JULY 25, 1965 STORM

On July 25, 1965, a moderately severe thunderstorm in a squall line, to be referred to hereafter as the storm, swept across the Denver, Colo., area from northwest to southeast. Strong winds with gusts up to 70 m.p.h. were reported. Trees were uprooted, and 1-in. hail damaged gardens; Stapleton Field reported small hail and 2.05 in. of rain. The heavy rain storm lasting 30 min. caused local flooding of streets. Figure 3 shows a portion of the Weather Bureau surface weather map for 0100 EST July 26, 1965 (0600 UT). This is 6½ hr. after the first infrasonic observation of the storm. This map shows the south end of a squall line near Denver.

At the infrasonic sites 20 to 75 km. to the north of the storm (see fig. 4) the local turbulence was very low, so that it was possible to track the azimuthal movement of the storm for 100 min. as the storm moved laterally with respect to the array of microphones. Range information is not derived from the infrasonic measurements.

Radar data on this rapidly moving storm were not available. The approximate path of the storm is shown in figure 4, based on visual reports. These include reports from Weather Bureau personnel at Jefferson County Airport and Stapleton Field, U.S. Air Force observers at Lowry Field, contract employees at Buckley Field, and other reports. The storm appears to have started near the mountains in or near South Boulder or Coal Creek Canyons. At Eldorado Springs, at the mouth of South Boulder Canyon, 0.92 in. of rain occurred. The path crossed Jefferson County Airport, Lowry, and Stapleton Fields (see table 1). The storm passed well to the south of Buckley Field, and Sky Ranch Airport east of Stapleton Field continued to land small aircraft diverted from Stapleton Field during the storm.

The superposed graphic records from the four microphone sites are shown in figure 1. These records were adjusted for best fit at about 2300 UT. At 2255 and 2305

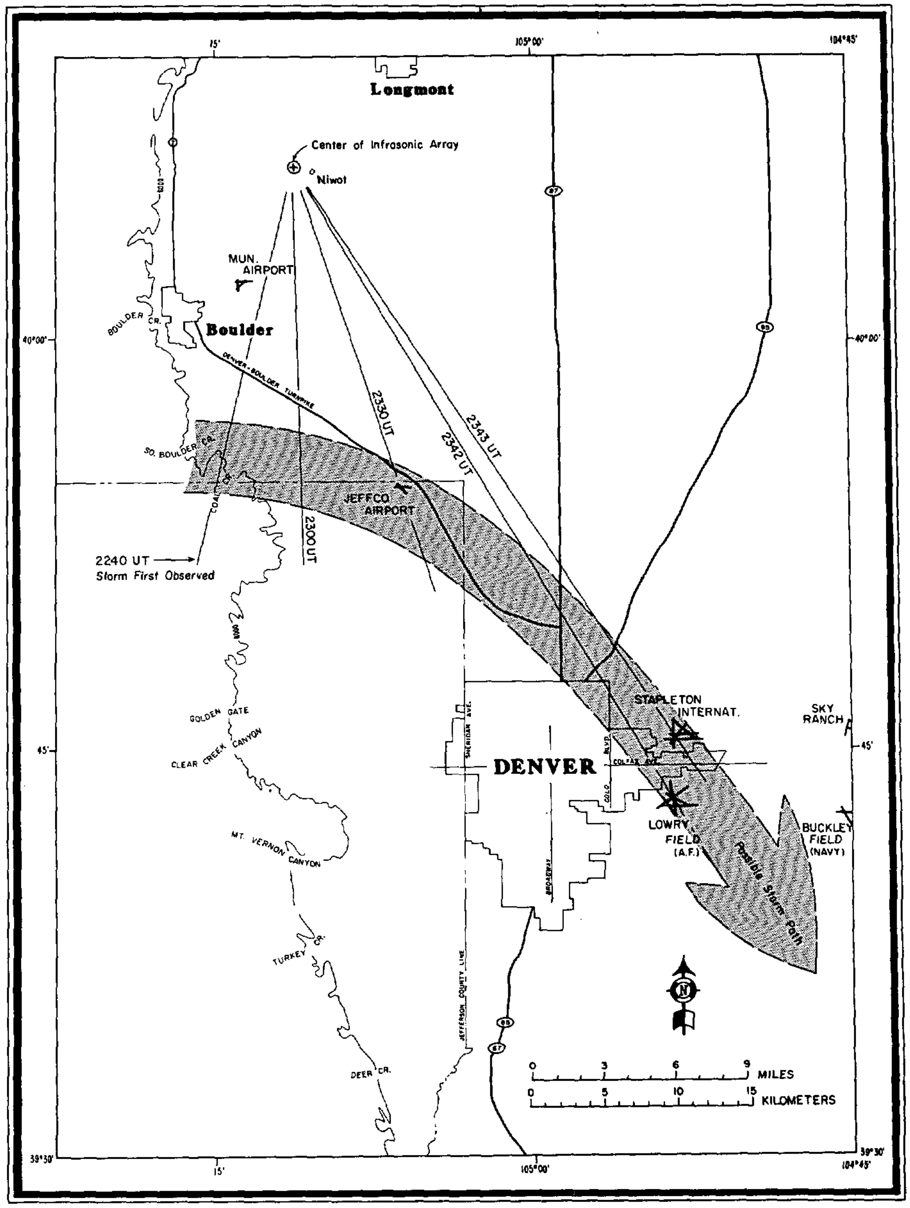

FIGURE 4.—Area map showing path of storm and observed azimuths to infrasonic source.

TABLE 1.—*Storm movement*

Visual observation of storm progress		Wind speed (m. sec.$^{-1}$)	From center of microphone array		
Location	Arrival time (UT)		Azimuth to airports (deg.)	Azimuth to storm (deg.)	Distance to storm (km.)
Jefferson County Airport	2330		161.5	162	24
Lowry Field (USAF)	2341	17.0 (33 kt.)	150.0	154	51
Stapleton Field (Denver Airport)	2346	27.3* (53 kt.)	146.5	135	47

*at 2350.

it is evident that the records are no longer properly superposed as a result of the rapid change in azimuth as the storm moved laterally with respect to the microphone array. The amplitude variations with time are typical of such events indicating varying emission from the source.

Each plotted point in figure 2 represents the correlator reading of an 8-min. average azimuth centered on the time indicated. Scaled azimuths are repeatable to 1 deg. over much of the period of observation. The signal was highly correlated from 2240 to 2330 and fairly good throughout the observations. This indicates that infrasonic emissions from other directions were not present during this event. The transit times of the infrasonic waves from the storm to the microphones were less than

3 min. and have been neglected in the plot. The exact time of arrival of the leading edge of the storm at Lowry and Stapleton Fields is subject to some interpretation. From the (WBAN) reports the onset of the storm at Stapleton was sudden whereas at Lowry it was more gradual.

From the smoothness of the azimuth variation with time and the good agreement with the surface observations of the storm onset times at Jefferson County Airport Lowry Field, and Stapleton Field, the region of emission of the infrasonic waves must have been in or near the leading edge of the storm at all times. Heavy rain continued for about 30 min. after the passage of the storm front. Funnel clouds were noted southeast of Buckley Field in the WBAN Report at 2225 and 2237, and south-southeast at 2315 and 2322 UT at azimuths quite different from the azimuths observed on the infrasonic correlator. There is no indication of infrasonic emission from these clouds on the records.

The maximum infrasonic wave amplitude was 0.8 dyne/cm.^{2} zero-to-peak. The highest amplitudes were observed from 2250 to 2320 UT while the storm was still near the mountains and nearest the microphone array. The median horizontal trace velocity across the microphone array was 340 m./sec. The infrasonic wave was received via line-of-sight transmission rather than via the earth-mesosphere waveguide responsible for long distance transmissions, as indicated by the horizontal trace velocity across the array (low angle of arrival). The observed amplitudes indicate that this was a moderately weak infrasonic event. Severe weather sources several hundreds of kilometers distant usually show amplitudes in the range of 0.5 to 4.0 dyne/cm.^{2} The observed periods were mostly in the range 20–25 sec. which is typical for many such severe weather events. Occasional events show periods up to 40–50 sec.

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3. CONCLUSIONS

The infrasonic source for the severe weather system of July 25, 1965 was confined to a single region closely associated with the leading edge of the storm, probably in the region of maximum convective forces. Infrasonic waves were not observed from the following heavy rain clouds or from funnel clouds which were observed visually well away from the storm front. The measurements reported here indicate the utility of infrasonic methods for tracking severe weather systems.

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